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# THE DEVELOPMENT OF SCAPHITES

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## INTRODUCTION

The material used in this study is that of the Paleontological Collection of Leland Stanford Junior University, and includes material collected from two very different localities.

In 1900 Mr. Milnor Roberts collected, in the vicinity of Sand Springs, thirty miles north of Wibaux, Mont., a suite of fossils, the majority of which were *Scaphites*. The rock is a dark, very hard and compact limestone, and contains the following genera and species:

*Scaphites nodosus*
*Scaphites nodosus var. brevis*
*Scaphites nodosus var. plenus*
*Scaphites nodosus var. quadrangularis*
*Scaphites mullananus*

With these occurred:

*Nautilus dekayi*
*Inoceramus barabini*
*Inoceramus sagensis*
*Antalis* ——
*Volsella meekii*
*Baculites ovatus*
*Pyrafsus (Neptunella) subturritus*
*Protocardia salinaensis* (?)
*Protocardia rara*
*Neæra ventricosa*

All of these, and many more, are figured in the reports of the Hayden Survey of the Territories, and by Stanton,[1] and referred to the Fort Pierre horizon of the Upper Cretaceous.

Stanton records a similar fauna from the Cretaceous rocks of Nebraska, where the following species are contained in dark gray and bluish plastic clays:

*Nautilus dekayi*
*Placenticeras placenta*
*Baculites ovatus*
*Scaphites nodosus*
*Inoceramus nebrascensis*
*Dentalium graciale*
*Crassatella evansi*
*Cuculala nebrascensis*
*Inoceramus sagensis*
*Inoceramus vanuxemi*
Bones of *Mosasaurus missouriensis*

The beds also occur on Sage Creek, Cheyenne River, and on White River above the Mauvaises Terres in South Dakota. Mr. Stanton also states that these same beds are exposed in central Colorado and contain:

*Nautilus dekayi*
*Baculites ovatus*
*Baculites compressus*
*Inoceramus cripsii*
*Inoceramus proximus*
*Placenticeras placenta*
*Avicula linguiformis*
*Sphenodiscus lenticulare*
*Scaphites nodosus*
*Ptychoceras mortoni*
*Heteroceras* (several specimens)
*Anisomyon*
*Lucina occidentalis*
*Avicula nebrascensis*, etc.

Clearly, then, the suite from Montana belongs to the Fort Pierre horizon of the Upper Cretaceous, and is, as far as we know, confined to that horizon only. *Scaphites nodosus* certainly is characteristic of that horizon.

The other group of Scaphites is from the Pacific coast province and from the horizon known as the Lower Chico, Upper Cretaceous. The specimens I have used were collected and described by Mr. F. M. Anderson,[2] paleontologist for the California Academy of Sciences, from the '49 mine near Phœnix, Ore.

These occur in soft, yellowish sandstone, with the following characteristic fossils:

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[1] T. W. Stanton, *The Colorado Formation and its Invertebrate Fauna*, 1893, Bulletin No. 106, U. S. Geological Survey.

[2] F. M. Anderson, "Cretaceous Deposits of the Pacific Coast," *Proceedings of the California Academy of Sciences*, 3d series (1902), Vol. II, No. 1.

*Desmoceras hoffmani*
*Desmoceras sugatum*
*Desmoceras ashlandicum*
*Baculites chicoënsis*
*Helicoceras breweri*
*Helicoceras declive*
*Ancyloceras lineatum*
*Lytoceras sacya*
*Lytoceras jackonense*
*Lytoceras jukesi*
*Placenticeras pacificum*
*Schœnbachia oregonensis*
*Arethusa californica*
*Nautilus sp.* (?)
*Scaphites inermis*
*Scaphites condoni*
*Scaphites gillesi*
*Scaphites perrini*
*Scaphites roguensis*
*Scaphites klamathensis*

The first two in the list of *Scaphites*, *S. inermis* and *S. condoni*, have been selected for study principally for the reason that there was more material of these two species available for the work.

In connection with these the following have been studied:

*Sonneratia stantoni*
*Desmoceras beudanti*
*Desmoceras hoffmani*
*Lytoceras alamedense*
*Baculites chicoensis* } chiefly from the papers by J. P. Smith.[1]
*Pachydiscus*

All drawings have been made with the camera lucida, either with or without the microscope.

The very young stages have in most cases been enlarged thirty diameters, and some of the larger adolescent stages only ten, while the adults are represented at natural size.

The writer wishes to express his appreciation of the valuable aid, in the matter of suggestions and in furnishing some excellent material to work on, rendered by Professor J. P. Smith. Acknowledgments are also due Professor Stuart Weller for valuable assistance and opportunity extended to the writer to examine material from the Upper Cretaceous of New Jersey.

## DESCRIPTION OF SPECIES

The writer does not feel called upon to add to or repeat the description of these forms as found in Meek's or Anderson's works, more than to state just enough to aid the reader and save him the trouble of referring to these larger works.

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[1] J. P. Smith, "Development of Pytoceras and Phylloceras," *Proceedings of the California Academy of Sciences*, 3d series, Vol. I, No. 4; "Larval Coil of Baculites," *American Naturalist*, Vol. XXXV (1901), No. 409.

*Scaphites nodosus* Owen is by far the largest Scaphite of those mentioned in this paper. It is, like all of the *nodosus* group, coarse-ribbed in the neanic and ephebic stages, growing more smooth on the abnormal body chamber where the coil leaves the true spiral. It has strong nodes on the ventral shoulders, and sometimes also on the umbilical shoulders. The form is quite robust and is remarkable for its long, last body chamber which has left the whorl partly and turned back on itself somewhat as in the case of *Macroscaphites*, though not so pronounced.

*Scaphites nodosus brevis* is coarse-ribbed, but shows no nodes on the umbilical shoulders, and is a much smaller form, less gibbous, and just beginning to leave the coil. *S. nodosus plenus* is simply a very gibbous form, with about the same dimensions as *brevis*. Its suture in the adult is somewhat different, and the nodes are not so pronounced. *S. nodosus quadrangularis* can be distinguished from *brevis* only by its flattened dorsum and the very small nodes on the umbilical shoulders.

*S. mullañanus* is slightly smaller than the others, and, as far as the writer can determine, does not leave the coil at all, and possesses no abnormal body chamber. Nodes are altogether lacking, the ribs coarse and passing from umbilicus to umbilicus.

The two Oregon species are very much smaller than those mentioned above, flatter, and almost devoid of ornamentation. At the very end of the last coil there is a slight departure from the coil and a constriction around the coil just back of the aperture. The largest of these would not be more than $15^{mm}$ in diameter. *Scaphites condoni* has a slight wrinkling or development of ribs on the side of the adult coil, but no nodes. *S. inermis*, on the other hand, possesses a row of very small nodes on the ventral shoulder or the last coil. They are both extremely thin forms.

*S. nodosus* Owen, which is not shown in the plate, measures about $3\frac{1}{2}$ inches in diameter along its longest axis; *S. nodosus brevis* and the others, about 2 inches and less. They all have narrow umbilici. This is quite the opposite from what we find in the Oregon species.

## DISTRIBUTION

The type of this comprehensive genus was first found in Dorsetshire, England, by Parkinson,[1] in the year 1811. *Scaphites*, however, is well known from many parts of Europe and also India. Logan[1] thinks that all known *Scaphites* originated from one species in the Gault of Europe, the Gault being transitional from the Lower to the Upper Cretaceous, and have migrated from Europe to India and to America. At that time he thought *Scaphites* monophyletic, but the recent discovery by Mr. Anderson in the Upper Cretaceous of Oregon and California of some new scaphite forms with different ontogeny, and mingled with an entirely different fauna, makes it highly improbable that this is so.

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[1] Parkinson, *Organic Remains*, Vol. III, p. 145, Pl. X, Fig. 10.

According to Anderson,[2] there was probably a communication established between the Interior Sea of America and the Pacific province in Upper Cretaceous time, but none up to that time, unless we go back of the Jurassic. However, J. P. Smith[3] has shown that there was a connection between the Indian province and the west coast of America. An examination of the plates in the volume on the Cretaceous fauna of India reveals a striking similarity between the Indian *Scaphites* and those in the Pacific province.

On the other hand, the fauna of the western Interior Sea is known to be very similar to, if not identical with, faunas in just the other direction. The writer has seen some *Scaphites* from the Upper Cretaceous of New Jersey in Professor Stuart Weller's collection which appeared to be of the same type as those coming from Montana. Much the same fauna has been described from Texas and Alabama. This seems to make it quite conclusive that migration took place along the Cretaceous coast line from the eastern border around by the Mississippi embayment up into the interior. Having got as far as the Atlantic coast, we can explain the migration from western Europe in much the same way as the migration from the Indian province to western America.

As the writer will attempt to show, the ontogenetic study of the forms from the two regions, west coast and interior, simply corroborate these conclusions.

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[1] Field Col. Mus. Pub. 36, Geol. Ser., Vol. 1, No. 6.

[2] Anderson, *loc. cit.*, p. 67.

[3] J. P. Smith, "Periodic Migrations between the Asiatic and the American Coasts," *American Journal of Science*, Vol. XVII.

## ONTOGENY AND PHYLOGENY

### **Scaphites nodosus** var. **brevis**

*Ontogeny.*—This particular species or variety has been selected on account of its typical development, and because of the amount of material from which young stages could be worked out.

According to Logan,[1] *Scaphites nodosus* goes through the following stages in arriving at maturity:

1. Anarcestes.
2. Tornoceras.
3. Glyphioceras.
4. Gastrioceras.
5. Paralegoceras.
6. Pronorites.

In Fig. 3, the writer has placed, for purposes of comparison, some drawings of the sutures of typical species from the above-mentioned genera. Beyond a rather general similarity to *Glyphioceras,* the writer can see no reasons for correlations. It would be seen, too, from Branco's[2] excellent work on the young stages of ammonites, that many ammonites, and especially of the Jura and Cretaceous, have a Glyphioceran type of suture. It is thought by some that this does not mean kinship with Glyphioceras at all, but that it is a character acquired later, and pushed back by inheritance and acceleration until it is now found in the larva. In support of this, Professor J. P. Smith cites the development of *Pronorites* that possesses a Glyphioceran type of suture in its early stages of development, but which is clearly known not to have come through *Glyphioceras* at all.

In Logan's paper the suture is made the sole basis upon which relationships are based, and this lends itself to much criticism. As Professor Smith and the late Alpheus Hyatt have both respectively claimed, the suture cannot be taken as the sole criterion. Size of whorl, shape of whorl, ornamentation, etc., must be taken into account.

Numbers 9 to 11, Fig. 1, show the protoconch of this species. It is not, in essentials, very much unlike the protoconchs of many

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[1] Logan, *loc. cit.*, p. 210.

[2] Branco, *Entwickelungsgeschichte der fossilen Cephalapoden.*

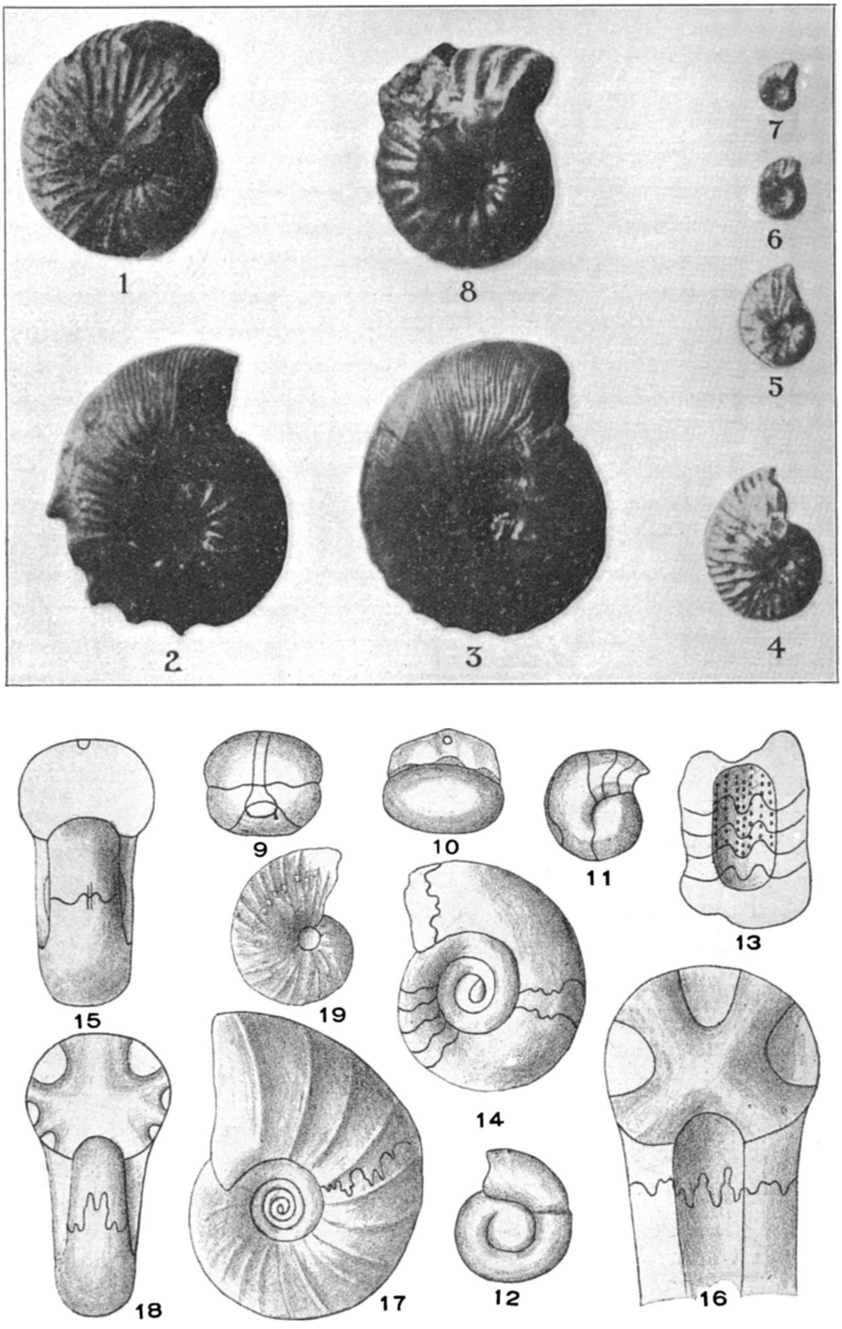

FIG. 1.—1, *Scaphites nodosus* var. *plenus;* natural size. 2, *S. nodosus* var. *brevis;* natural size. 3, *S. nodosus* var. *quadrangularis;* natural size. 4, *S. nodosus* var. *brevis* (Young); natural size. 5, *S. nodosus* var. *brevis* (Young); natural size. 6, *S. nodosus* var. *brevis* (Young); natural size. 7, *S. nodosus* var. *brevis* (Young); natural size. 8, *S. mullananuis.* 9–11, *S. nodosus* var. *brevis* (protoconch); ×30. 12, *S. nodosus* var. *brevis;* $D = 1.14^{mm}$. 13, *S. nodosus* var. *brevis;* inside of first whorl at D of $66^{mm}$; ×30. 14, *S. nodosus* var. *brevis;* $2\frac{5}{6}$ whorls, D of shell $= 2.26^{mm}$; ×10. 15, *S. nodosus* var. *brevis;* $2\frac{3}{4}$ whorls, $1.76^{mm}$; 20 D. 16, *S. nodosus* var. *brevis;* internal suture of the above. 17, *S. nodosus* var. *brevis;* $5^{mm}$; ×9. 18, *S. nodosus* var. *brevis;* $3\frac{3}{4}$ whorls; ×4.

Mesozoic ammonites. It is about $\frac{1}{2}^{mm}$ wide and is calcareous, marked with regular rows of small pustules, as in *Lytoceras,* and shows very plainly the siphonal cæcum and siphonal collars pointing forward. What these pustules mean is a matter, more or less, of conjecture; however, it is quite possible that these may be traces of the ornamentation of some ancestor, either *Goniatites strictus,* which in the adult stage shows markings not greatly unlike these, or an ancestor of both. At any rate, they represent a character very remote which has been pushed back now into the embryonic stage. These pustules cease abruptly at a constriction in the shell which occurs at a diameter of $0.66^{mm}$, or about one revolution. This is shown in Number 13, Fig. 1.

The protoconch is wider, invariably, than the first coil in all species of *Scaphites* studied during this work, and this is true also in the case of *Baculites* and *Lytoceras,* as will be seen from an examination of the plates in Professor Smith's papers.

The first septum is angustisellate. According to Hyatt, this is called the ananepionic stage, and shows that the animal has in its ontogeny a stage which in the history of the race is that of a nautiloid. (The sutures are shown in Fig. 3.)

With the second septum, which is marked by the development of a siphonal lobe, the animal becomes an Ammonoid. This stage is called the metanepionic or second larval period. Right here may be mentioned one thing that indicates the highly accelerated nature of some characters, and the unequal acceleration that may be found in these later Ammonites In the *Orthoceratidæ* and *Nautilinidae* the siphuncle is central in the former, and just a little distance away from the center in the latter, migrating gradually in the later Nautiloids and Goniatites toward the margin of the coil, until in the ammonites it is marginal. But here, in the very early stages, which are nautilian and goniatitic, we find the siphuncle marginal, and also the collars prosiphonate (these characters could be made out on only the first four septa). In the early cephalopods the collars are retrosiphonate. So we have very great acceleration of some characters compared with others. This in itself makes it quite probable that the sutures are highly modified by acceleration of characters introduced late in the history of the race, and likewise lessens the prob-

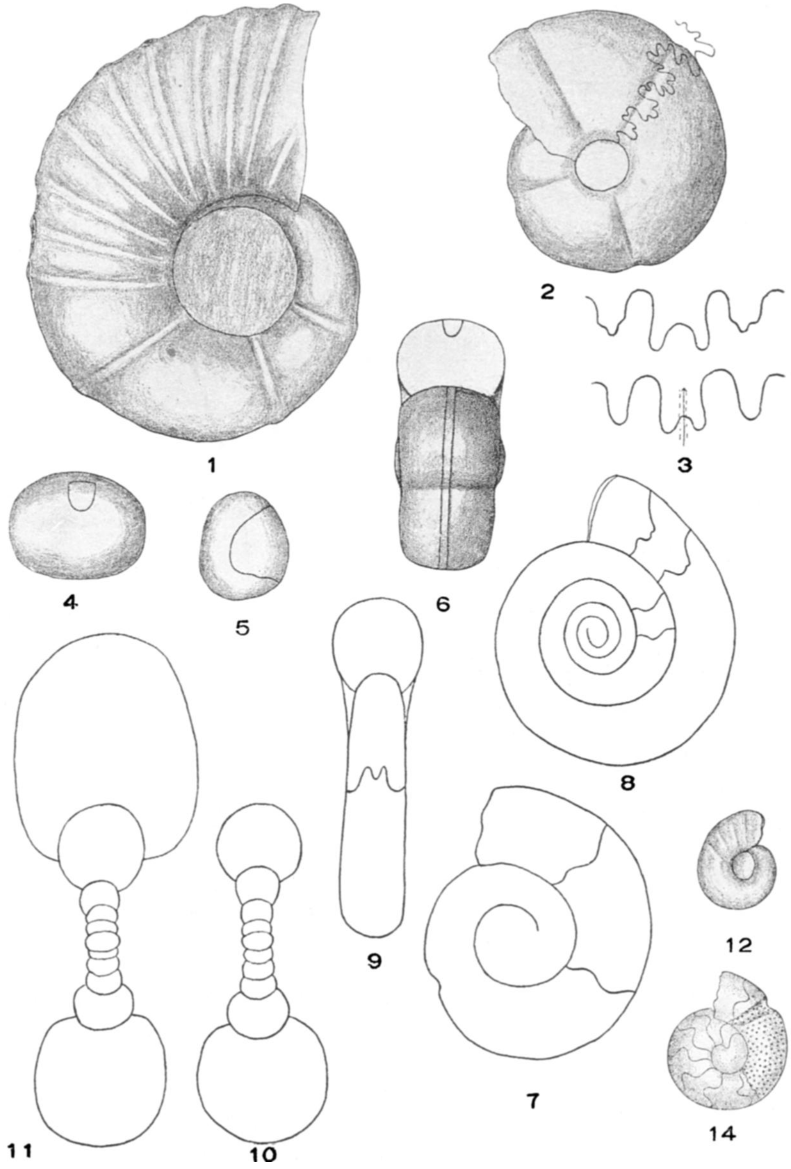

FIG. 2.—1, *Scaphites nodosus* var. *quadrangularis;* ×7. 2 and 3, *Desmoceras hoffmanii;* ×10; 4$^{\mathrm{mm}}$; showing constrictions and development of sutures; 3 represents a much younger stage. 4, *S. condoni* and *inermis* protoconch showing cæcum. 5, Side view of protoconch; ×30. 6, Same at D. of 8$^{\mathrm{mm}}$; ×30. 7, Same at 8$^{\mathrm{mm}}$; ×30. 8, Same at 4$^{\mathrm{mm}}$; ×8. 9, Same at end view; 4$^{\mathrm{mm}}$; ×11. 10, Cross-section of *S. inermis* (half whorl missing). 11, Cross-section of *S. condoni;* ×7. 12, Adult of *S. condoni.* 14, Larval coil of *Baculites chicoënsis.*

ability of their being in close relationships with the ammonoids that Logan cites.

At $0.66^{mm}$ diameter a constriction was found on one individual (Number 12, Fig. 1), while again specimens were broken back to the protoconch and not a constriction seen. In others it was found recurring several times in the same individual. However, there is no constancy about this feature, as in *Baculites*, *Desmoceras*, and many others (Number 2, Fig. 2). In *Baculites* this is, according to J. P. Smith, a very constant feature, and comes always at the end of the larval coil, i. e., one revolution. In several specimens of *Scaphites condoni* and *S. inermis* this constriction has been noted by the writer at about three-quarters of a revolution from the protoconch.

In the Montana species this is taken by the wrier to be purelyt an individual character, and one likely to be found at almost any point in the development of a phylogerontic group. It means simply that there is a pause now and then in the growth of the animal, as should be expected in the members of a group that we know was then on the decline.

From this point on the shape of the aperture changes rapidly from a crescentic to a more roundish form, due to heightening of the walls, and when the adolescent period is reached, the aperture is almost circular (Number 16, Fig. 1). The adolescent period, in the species studied, has not been found to begin at any constant size. The notching of the first lateral lobe, when it becomes, to use a techincal term, bifid, is assumed to be the beginning of the adolescent period. In one specimen this stage began at a diameter of $1.87^{mm}$, in another at $2^{mm}$, in a third at $2.26^{mm}$, while a fourth continues in a larval state up to $2.48^{mm}$, or $2\frac{11}{12}$ revolutions.

Number 14, Fig. 1, shows a smooth shell of this form and the sutures. The umbilicus is quite wide still, and the shape of the aperture little changed. From this point on, however, the whorl increases rapidly in height and width, and the whole shell becomes thicker. In *S. nodosus* var. *plenus* this growth is very sudden and marked, as will be seen by referring to 7 and 8, Fig. 3.

Some measurements to show the relative growth at the different sizes will doubtless be more useful than a verbal description:

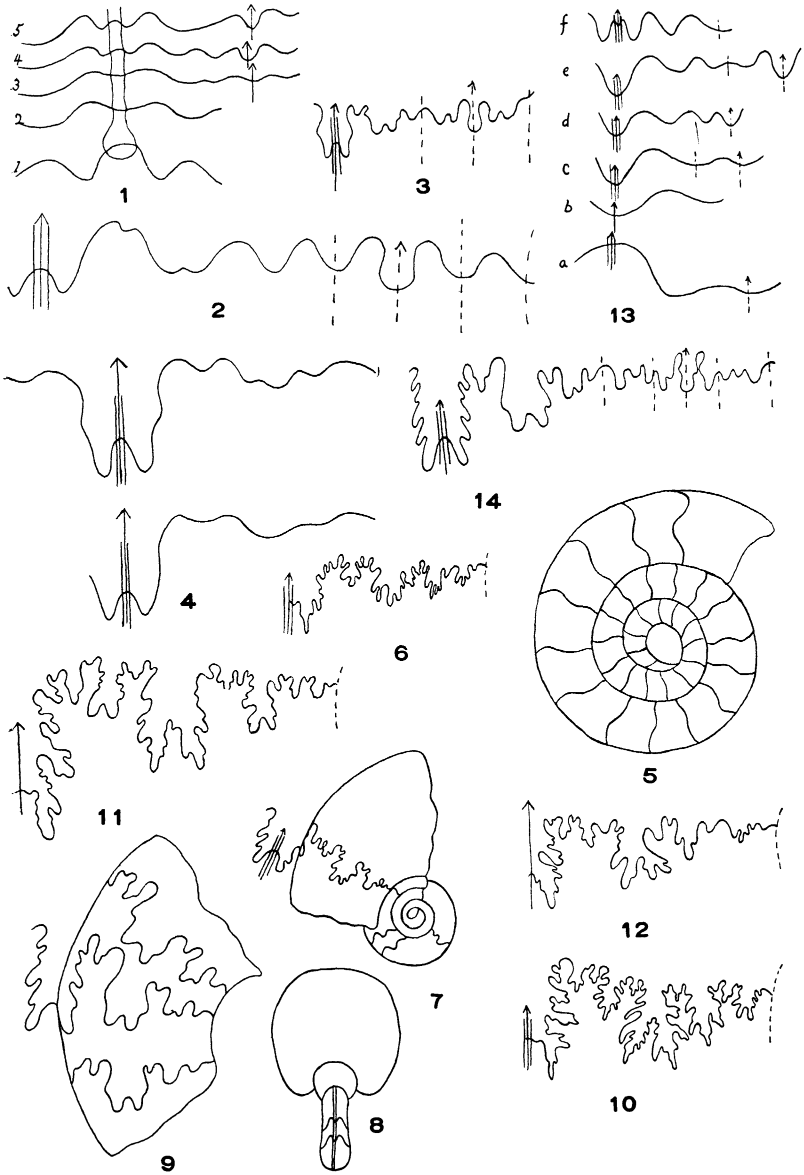

FIG. 3.—1, First five sutures of *S. nodosus* var. *brevis;* ×30. 2, Suture at 2.26$^{mm}$; ×30. 3, Suture at 4$^{mm}$; ×10. 4, Suture of *S. nodosus* var. *plenus* at 3$^{mm}$; 2$\frac{7}{8}$ whorls; ×30. 5, Side view of *S. nodosus brevis* showing sutures 1.76$^{mm}$; 2$\frac{3}{4}$ whorls 20 D. 6, Adult suture of *S. nodosus brevis;* 28$^{mm}$; natural size. 7, *S. nodosus plenus* at 6$^{mm}$; ×7. 8, End view of same. 9, *S. nodosus brevis* at 5$^{mm}$; ×10. 10, *S. nodosus plenus* adult; natural size. 11, *S. mullananus* adult; ×3. 12, *S. condoni* and adult; ×5. 13, First six sutures of *Glyphioceras diadema* (Branco). 14—Internal suture of *S. nodosus* at same size as that shown in Number 9.

TABLE I[1]

*S. nodosus* var. *brevis*

| | I<br>Proto-conch<br>mm | II<br>½ Whorl<br>mm | III<br>1 Whorl<br>mm | IV<br>1½ Whorls<br>mm | V<br>2<br>mm | VI<br>2½ Whorls<br>mm | VII<br>mm | VIII<br>Adult<br>mm | IX<br>mm |
|---|---|---|---|---|---|---|---|---|---|
| Diameter of shell... | 0.40 | 0.56 | 0.78 | 1.04 | 1.50 | 2.18 | 5.00 | 20.0 | 5.00 |
| Height of whorl... | 0.40 | 0.26 | 0.30 | 0.46 | 0.60 | 0.90 | 2.40 | 12.0 | 2.20 |
| Width of whorl.... | 0.46 | 0.48 | 0.50 | 0.60 | 0.76 | 1.12 | 2.50 | 13.0 | .... |
| Involution......... | .... | 0.08 | 0.10 | 0.14 | 0.20 | 0.22 | 0.42 | 3.0 | 0.50 |
| Width of umbilicus | .... | .... | .... | .... | 0.86 | 1.22 | .... | 6.0 | 2.00 |

From these figures we see that the protoconch is wider than the first coil, and consequently must bulge beyond it (see also Number 15, Fig. 1). The first few whorls, up to the third, are slender, and the umbilicus is correspondingly wider proportionally than in the case of the mature form. The involution in the larval and adolescent stages remains fairly constant, about 1 : 3, i. e., embraced part of the coil to the exposed portion; while in the adult it is 1 : 4 and 1 : 5, becoming less and less until in the old or senile stage the involution becomes negative, i. e., the outer coil begins to leave the inner coil. In both the Pacific province forms and those from the interior an impressed zone at the end of the last body chamber can be seen, which shows clearly that these animals were once coiled throughout, not these particular individuals, but the earlier members of the group.

At the beginning of the adolescent stage the following are the measurements:

| | mm |
|---|---|
| Diameter of shell - - - - - - | 2.26 |
| Height of whorl - - - - - - | 0.76 |
| Width of whorl - - - - - - | 0.84 |
| Involution - - - - - - | 0.12 |

The shell at this stage is absolutely devoid of any marked sculpturing, save the presence of very fine lines of growth running around the coil, parallel to the outline of the aperture. The sutures continue developing gradually. The first change noticed is the development of marginals on the siphonal lobe. Then between the siphonal lobe and the first lateral lobe, and likewise between all the principal lobes, develop smaller secondary lobes. Fig. 3, Number 3, shows the suture at a diameter of $4^{mm}$.

[1] VII and IX different individuals.

At a diameter of $5^{mm}$ the shell is seen for the first time to be sculptured. A slight wrinkling of the surface is first noticed, and this soon becomes well defined costæ, and a little later nodes develop on the ventral shoulders. The costæ are seen to begin on the sides of the coil, running away from the nodes in one direction to the umbilicus, in the other across the venter. The sutures are in number of lobes, and in every way, save in minor, secondary digitations between the lobes, essentially adult. The internal lobes and saddles have changed very much from the types seen in the embryonic stage. These changes are shown in Fig. 3.

The way in which the ribs and nodes begin is interesting, and may be briefly outlined. First, there appears a slight wrinkling along the sides of the whorl; then there is to be seen a swelling along the ventral shoulder line. From these slight protuberances the costæ bifurcate in crossing the venter, but come together at the node on the opposite side. Between these, and later, a short rib develops on the venter, passing round on the sides afterward. In the adult stage more ribs are intercalated in the same manner. On the abnormal body chamber the ribs grow finer, and the nodes or tubercles cease abruptly (Numbers 2 and 3, Fig. 1). *S. nodosus quadrangularis* is the only one in all the forms studied to show nodes on the umbilical shoulders. They are never very prominent, however.

The abnormal body chamber or living-chamber, *anormaler Wohnkammer* of the Germans, marked not only by lack of sutures and diminuation of sculpturing, but in another characteristic, that of leaving the true spiral, is the last living-chamber. In the several species and varieties this is by no means constant. Here are some measurements, diameters at which this chamber begins:

| | mm |
|---|---|
| *S. nodosus* var. *brevis* - - - - | 29 |
| *S. nodosus* var. - - - - - - | 30 |
| *S. nodosus* var. - - - - - - - | 35 |
| *S. nodosus* var. *quadrangularis* - - | 37 |

*S. nodosus* Owen has a very long body chamber, and, having only one specimen, the writer could not break this off. It begins, though, at about the same diameter as the other varieties. *Scaphites nodosus* var. *plenus* differs in the adult from *brevis*, as will be readily seen in an examination of Numbers 1 and 2, Fig. 1, and Numbers 5 and 10, Fig. 3. The chief differences are the more gibbous form of *plenus*, and minor variations in the serrations and digitations of the suture. Up to the end of the larval stage, however, the two varieties are quite similar in every respect, but, as far as the writer has observed, *plenus* develops no nodes on the umbilicus. Number 8, Fig. 3, shows *plenus* at a diameter of $3\frac{1}{2}^{\mathrm{mm}}$ where the great change in size of coil comes in. No specimens of the variety *plenus* were found showing a tendency to uncoil, and, furthermore, no crowding of the septa. It appears to be more normal and less degenerate than any of the forms studied. The young *Scaphites nodosus* Owen is very like, practically indistinguishable from, that of *brevis* and *plenus*. This variety has grown to its extraordinary size due, no doubt, to more favorable conditions. The variety known as *quadrangularis*, whose adult stage has been briefly described at the outset of this paper, differs in the larval stage not materially from the other varieties. In the adolescent and early ephebic stages there is, on the other hand, quite a difference in the ribs, every fifth or sixth one being much more pronounced.

*Phylogeny.*—In studying the shape of the whorl, number of lobes and saddle of the sutures, and the digitations in each, the umbilicus and sculptures, the writer has been led to the conclusion that the *Scaphites nodosus* group is to be considered as having come from some member of the *Stephanoceratidæ*, or "crown-shaped" ammonites. The writer has compared the young stages of the *Scaphites nodosus* with the young of *Desmoceras hoffmani* and *D. beudanti*, also with *Sonneratia stantoni*, both from the Lower Chico of California and found many general relationships. These similarities are found in (1) the shape of whorl; (2) deep, narrow umbilicus; (3) number and digitation of lobes and saddles in the sutures.

However, there is one marked difference, but one which may be easily accounted for in a way to be explained later, in the lobes of the sutures of *Scaphites* and the forms just mentioned. *Sonneratia* and *Desmoceras* have throughout their development triænidian lobes. The development of such lobes can be seen in Fig. 3, Numbers 2 and 3. This type of suture is the normal type according to Haug.[1]

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[1] Emile Haug, "Les Ammonites du Permian et du Trias," extract from the *Bulletin de la Société Géologique de France*, 3d series, Vol. XXII (1894), p. 385.

*Sonneratia* and *Desmoceras* both change very materially in the ephebic stages, becoming very much flattened through an unusual increase in the height of the whorl. It is found, too, that the same style of suture is characteristic of both *Scaphites* and of the *Stephanoceratidæ*. This can be seen by looking through Sarasin's[1] paper. It is to be noticed, too, that some species of *Desmoceras* have a greater number of lobes than other species, and more than are found in *Scaphites*. In one specimen of *Scaphites nodosus quadrangularis* the writer found one stage, diameter $8^{mm}$, that resembled the adult of *Pachydiscus peramplus* Mantell, from the Lower Chalk of England. This is interpreted as being a reminiscence of characters belonging to some ancestor of both *Pachydiscus* and *Scaphites*. This was seen in no other specimen of any of the varieties. The sutures of neither form could be obtained for study, as the specimen of the *Scaphites* did not show it, and the original drawings of this species of *Pachydiscus* were not available.

*Pachydiscus wittekindi* Schlüter, from the Upper Chalk, also is not greatly unlike some of the early stages of *Scaphites*. Likewise there are reminiscences of *Macrocephalites*. These may be very superficial resemblances, but they are certainly suggestive.

## Scaphites inermis and S. condoni

*Ontogeny*.—These two very small species from the Cretaceous of Oregon and California are both figured in Mr. F. M. Anderson's *Cretaceous Deposits of the Pacific Coast*, already cited above. Their young stages are so nearly alike, up to the very last whorl, that where a number of the two species are thrown into a vial together, it is almost impossible to separate the two. Numbers 10 and 11, Fig. 2, shows the remarkable similarity of the two.

It was extremely difficult to get drawings with the camera lucida of the sutures of most of these specimens, for they are for the most part only casts, and the sutures do not show. The protoconch is not so rounded in these smaller species as in the interior forms, but otherwise is very little different. The cæcal bulb was seen in one case only, and that was not perfectly shown (Number 4, Fig. 2). At

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[1] Ch. Sarasin, "Quelques considérations sur les Genres, Hoplites, Sonneratia, Desmoceras, et Puzosia," extract from the *Bulletin de la Société Géologique de la France*, 3d series, Vol. XXV (1897).

.73$^{mm}$, $\frac{1}{2}$ revolution, there is a constriction which is quite as marked, when seen, as in the young *Baculites* and *Lytoceras*. The presence of pustules could be detected only faintly, not nearly as well marked as in *Scaphites nodosus*. The first lateral saddle is notched at a diameter of 3.4$^{mm}$, or $3\frac{3}{4}$ revolutions. At this stage the lobe is bifid, and not trifid, just as in the *nodosus* group, with this difference, that the forms of the *nodosus* group are more accelerated in this respect. There is very little change in either of these species in the adolescent and early ephebic stages, not as much as there is between Meek's varieties of *nodosus*.

It does not appear to the writer, after a study of these forms, that Mr. Anderson found enough differences to warrant him in calling them distinct species. It seems that they differ only in late ephebic stages, and then in a little minor sculpturing. The two are flat, rather thin, with no sculpture until the last coil. It is probable, however, that if these forms had given rise to any progeny, the descendants would have shown that these slight differences had been pushed back and added to until there would be no mistaking even the young.

As these forms were all preserved as casts, the shell itself could not be studied. Whether there was anything distinctive about it or not, resembling any other group, of course remains to be settled.

For comparison the following table has been drawn up:

TABLE II

*Scaphites inermis* And.

| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Protoconch | $\frac{1}{2}$ Whorl | 1 Whorl | $1\frac{1}{2}$ Whorls | 2 Whorls | $2\frac{1}{2}$ Whorls | 3 Whorls | $3\frac{1}{2}$ Whorls | 4 Whorls | $4\frac{1}{2}$ Whorls | 5 Whorls |
| | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm |
| Diameter of shell | 0.16 | 0.20 | 0.28 | 0.52 | 0.76 | 1.24 | 1.76 | 2.52 | 3.52 | 5.72 | 8.92 |
| Height of whorl | 0.16 | 0.04 | 0.08 | 0.24 | 0.24 | 0.48 | 0.52 | 0.76 | 1.00 | 2.20 | 3.20 |
| Width of whorl | 0.49 | 0.48 | 0.48 | 0.49 | 0.52 | 0.56 | 0.72 | 1.08 | 1.60 | 2.40 | 3.24 |
| Involution | Too small to measure | | | | | 0.6 | 0.14 | 0.28 | 0.48 | 0.20 | .... |
| Width of umbilicus | .... | ... | 0.36 | .... | 0.64 | .... | 1.24 | .... | 2.50 | ... | 4.50 |

*Ppylogeny*.—From a study of the young stages of *Baculites* and *Lytoceras*, both from the material itself and J. P. Smith's[1] papers, the writer has come to the conclusion that *Baculites* and *Lytoceras*, and these two species of *Scaphites*, had a common ancestor, or *Baculites* and *Scaphites* may have sprung from the *Lytoceratidæ*. Indeed, some are of the opinion that *Baculites* came from the *Lytoceratidæ*, and is a very degenerate descendant from this more normal and progressive family. The likeness of the young stages of *S. condoni* and *inermis* to the young of *Baculites* and *Lytoceras* is more in the general aspect of the shell rather than in any specific characters.

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[1] J. P. Smith, "Larval Coil of Baculites," *American Naturalist*, Vol. XXXV, No. 409; "Development of Lytoceras and Phylloceras," *Proceedings of the California Academy of Science*, 3d series, Vol. I, No. 4.

The interior forms of *Scaphites* soon change to forms with narrow, deep umbilici, and come to possess prominent ribs, while the two Pacific province forms do not develop in this manner at all, but remain thin and possessing wide umbilici. (See Numbers 8 and 9, Fig. 2.)

## ACCELERATION AND RETARDATION

Logan, in the above-cited article, said that the *Scaphites* from the Interior Sea, *Scaphites nodosus* group, were progressive ammonites. The writer is forced to take issue with Logan on this point. He concludes that they are not progressive, but degenerate forms, and, moreover, forms exhibiting unequal acceleration of certain characters, and hence retarded in the sense that Cope[1] meant. J. P. Smith[2] gives a summary of the work of Hyatt, Cope, and others on the underlying philosophical principles of paleontogeny, and the two laws, the former of which was formulated by Hyatt, and the second by Cope, are explained, so that they will not be stated again in this paper.

In the first place, both of these groups of *Scaphites* are degenerate, and they are considered so on these grounds: (1) in the possession of an abnormal body chamber, they show degeneration or senility; (2) in the dicranidian lobes; (3) in the reduced number of lobes and saddles; (4) in the fact that they have, so far as we know, left no trace of a descendant.

Pompeckj[3] concludes that the possession of the abnormal body chamber marks that particular ammonite as senile, and when the whole species possess it, then the term "phylogerontic" is used to describe the stage. Pompeckj does not agree with Hyatt in saying that this abnormal chamber may appear several times during the growth of the individual, and afterward be absorbed. On the other hand, he asserts that this chamber is always the last chamber.

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[1] E. D. Cope, *Origin of the Fittest.*

[2] J. P. Smith, "Comparative Study of Paleontogeny and Phylogeny," *Journal of Geology*, Vol. V (1897), No. 5, p. 508.

[3] J. F. Pompeckj, "Die Ammonoideen mit anormaler Wohnkammer," *Jahreshefte des Vereins für Vaterlandische Naturkunde*, in Würtenberg, 50. Jahrgang (1894), pp. 220–90.

In one individual only did the writer see anything that looked like a resorption phenomenon, but he is of the opinion that the peculiar swelling around the coil was due to some distortion of the shell. Cases where the individual paused in its growth, forming constrictions and building sutures close together, are quite common in *Scaphites*, but further than these nothing pointing to an abnormal chamber in the young stages similar to that found in the adult or senile stages was found.

All the normal, close-coiled, progressive ammonites, as far as the writer knows, have lobes triænidian. This also is the opinion of Haug, as stated above. On the other hand, *Baculites*, one species of *Lytoceras*, *L. alamedense*, and all the species of *Scaphites* studied show dicranidian lobes. In the matter of number of lobes it will be found, on examination, that many species of *Desmoceras* and many ammonites of the Trias and Jura possess more lobes than are found in the *Scaphites*. This is taken to be another sign of degeneracy.

It seems to the writer that the reduced number of lobes and saddles, and the lessening of the degree of digitation, in many of the varieties of the *Scaphites* may be satisfactorily explained by retardation, i. e., failure to reach the highly developed condition of their ancestors. In the fact, too, that we find simplified sutures and the normal whorls together, and the presence of nodes in the young stages along with other characters that are not signs of senility, we have evidence of retardation. The reminiscenses of *Pachydiscus* and *Macrocephalites*, also, in the young of *S. nodosus quadrangularis* point to unequal acceleration or retardation. From Beecher's[1] work on spines we know that these belong to the gerontic condition, and to find them appearing in the young stages at all shows the working of the law of retardation.

In Number 9, Fig. 3, is illustrated a very interesting point in this connection. If retardation be assumed to take place, it is clear that it will be noted first in the case of the lobes and saddles nearest the ventral lobe, for these are the oldest. In this figure the first auxiliary lobe is seen to develop normally into a triænidian lobe, while the first lateral develops in a dicranidian lobe. In time it is quite possible that through unequal acceleration all the lobes will become dicranidian.

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[1] C. A. Beecher, "Origin and Significance of Spines," *American Journal of Science*, Vol. VI (1898).

## VARIATION

In all the varieties and species of *Scaphites* studied the variation is seen to be very pronounced. In the variety *brevis* we find nodes away down in the young stages long before they appear in similar stages of *plenus* and *quadrangularis*. In the Oregon and California species we do not find them until the very last. In the ribs, too, there is seen to be a great diversity. We evidently have to deal with modifications, some of which have been acquired and pushed back in the ontogeny to earlier stages, and others that have been lately assumed. If we could find the progeny of some of these varieties, we might be able to see differences enough to warrant calling them species; for varieties, if given time enough, will undoubtedly produce species.

## CONCLUSION

We are of the opinion, then, from this study, that the genus *Scaphites* is in need of revision; that a number of "morphological equivalents," to use Hyatt's expression, have been grouped together as species of one genus; that this genus is polyphyletic, and not monophyletic, as it has been treated heretofore; that both groups of *Scaphites* are degenerate, phylogerontic forms; that the *nodosus* group, from Montana, sprang from some member of the *Sephanoceratidæ*, while the Oregon species probably originated from the *Lytoceratidæ*, or the ancestor of this group.

In the *nodosus* group we have a number of varieties that are on the road to becoming species. In the two so-called species from Oregon and California it is our opinion that we have varieties merely.

*Scaphites perrini*, found with *S. inermis* and *cononi* by Mr. Anderson, may have come, not from the *Lytoceratidæ*, but from *Stephanoceratidæ*. This is based on the aspect of the whorl, the young stages not being available for study.

These forms, then, sprang from the normal, close-coiled ancestors, but are themselves degenerate, partially uncoiling forms. They may be on the road to a state of complete abnormality, as *Baculites*, *Hamites*, etc., but at present have not gone very far in that direction.

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